TITAN SYSTEMS CORPORATION

AVERSTAR GROUP

A Case Study of IV&V Return on Investment (ROI)

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Independent Verification and Validation

Traditional Perspective on IV&V

- A Technical Discipline With a Software Focus
- Emphasis on Fielding a Viable System On-Time
- IV&V Costs Incidental Compared to Acquisition Costs
- A Means for Mitigating Risks

Emerging Perspective on IV&V

- A Technical Discipline Encompassing the Entire System
- Emphasis on Fielding a Viable and Affordable System
- Required That IV&V Be Cost Effective
- A Means for Reducing Risks

Net Result: Support for the Total Life Cycle

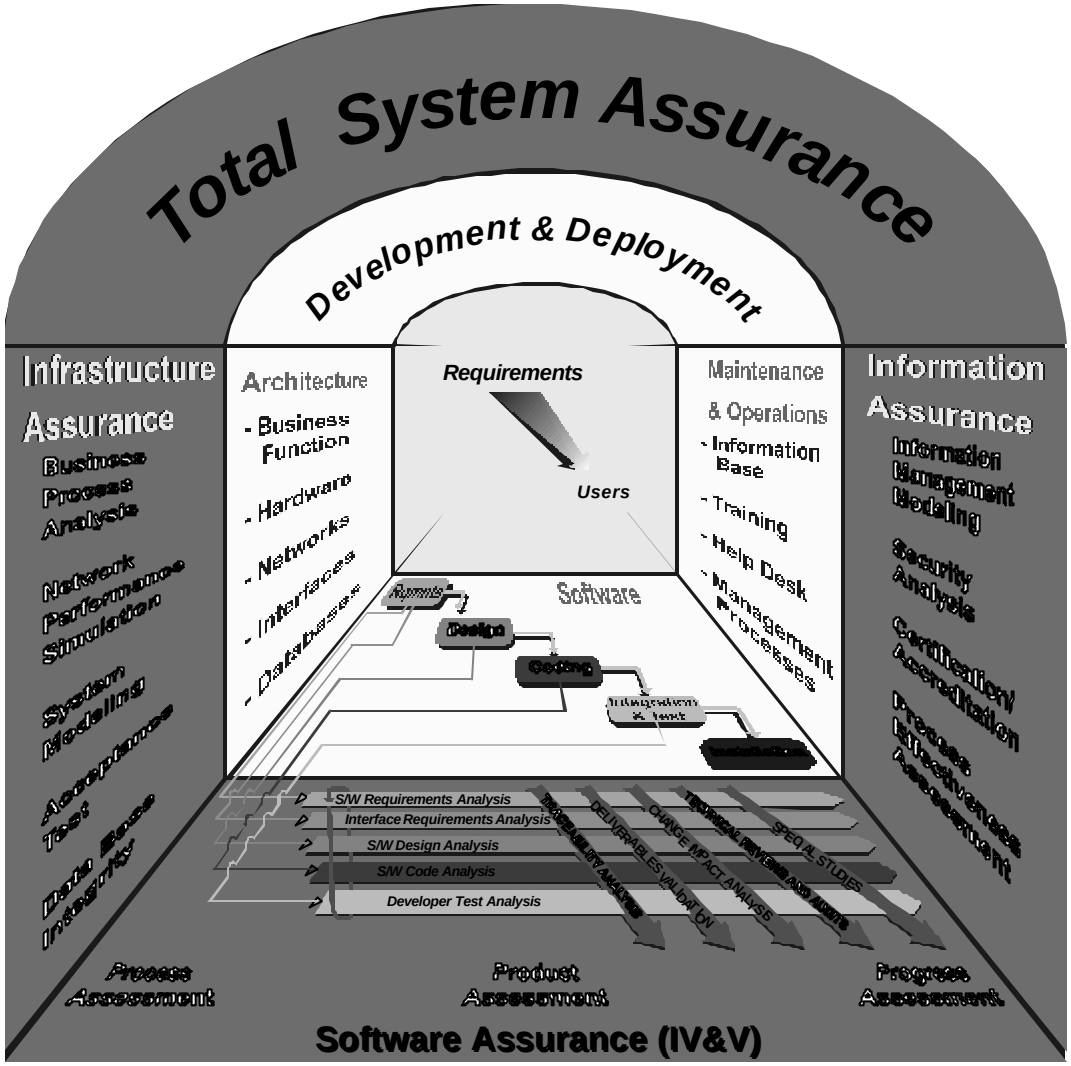
Total System Assurance Builds From the Historic Foundation of IV&V

- Expanded Scope Encompasses All Elements of the System
  - Infrastructure
  - Information Base
  - Software
- Increased Emphasis on Cost-Effective Utilization of Resources
  - Add Value by Eliminating Risks and Providing a Foundation for System Maintenance
  - Integrate into IPTs to Reduce Overall Development Costs
- Broadened Applicability Across All Aspects and Phases
  - Program Management as well as Technical Solution
  - Support Evolution/Enhancement Into Maintenance Phase

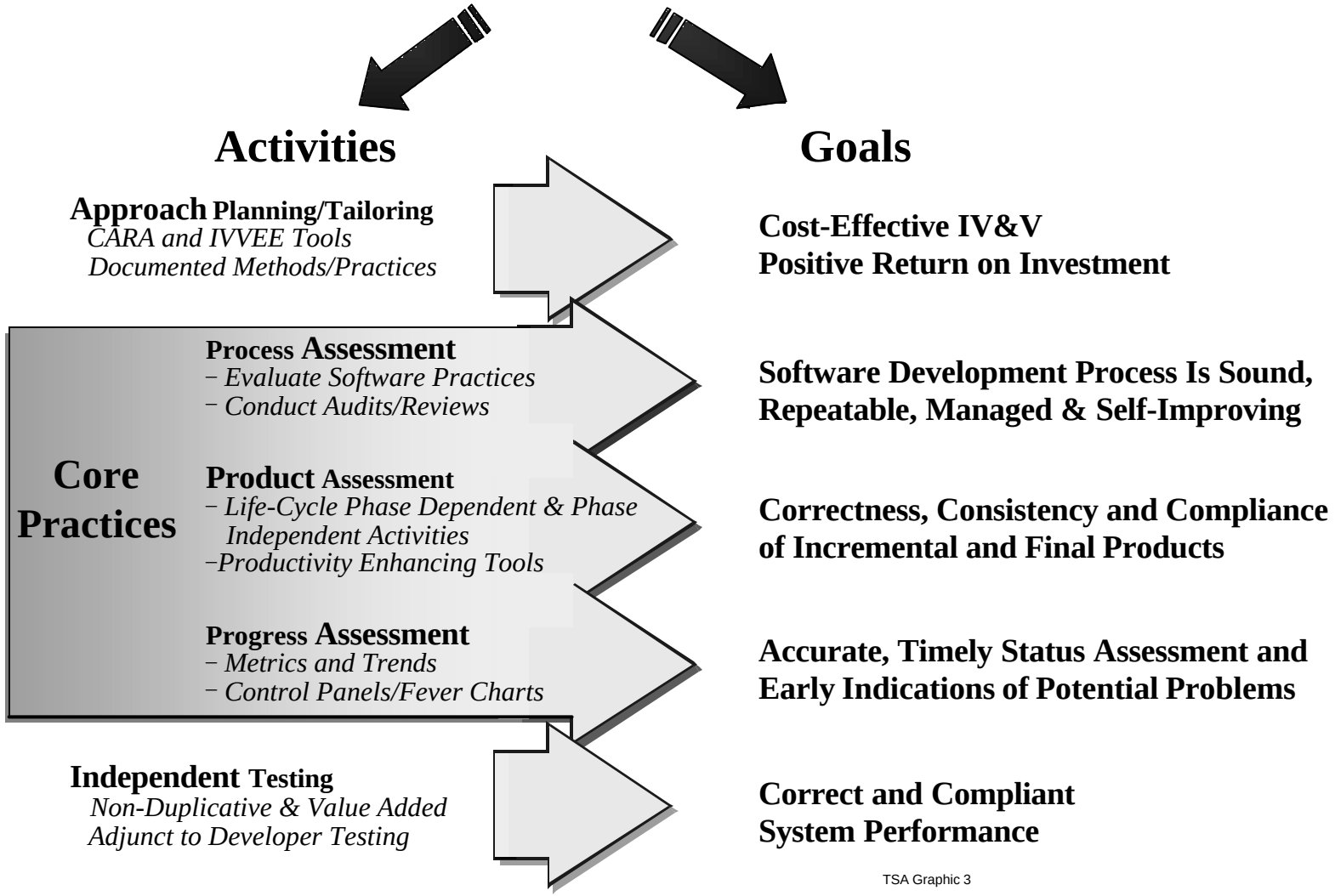
Objective: Reduce Total Ownership Costs

Total System Assurance

Concepts to Operations



Software Assurance Practices Are Goal Driven



TSA Graphic 3

Software Assurance (IV&V) Cost Effectiveness

- Subject of Considerable Debate
- Much Anecdotal Evidence
  - Problems Detected by IV&V
  - Early Life Cycle When Cheaper to Correct
- Doesn't Directly Yield a Cost Effectiveness Measure
  - Would the Developer Have Found the Same Problems?
  - When Would the Developer Have Found Them?
  - Actual Costs to Correct, Early Versus Late
- What If IV&V Finds No Significant Problems?
- Classical Control Study Experiment
  - Build the Same System Twice, Once With and Once Without IV&V and Compare Resultant Cost and Performance

Case Study Background

- Two NASA Space Shuttle Ground Systems Projects
  - Day of Launch I-Load Update (DOLILU) - develop, validate and up-link first stage guidance commands
  - Flight Analysis and Design System (FADS) - redesign/rebuild DOLILU software for hosting on distributed UNIX workstations
- Study Encompasses Software Assurance (IV&V) Only
  - Each Project Had Multiple CSCIs
  - Contractors and Development Regimes Differed for Individual CSCIs
  - IV&V Applied in Two Different Manners
    - Full Life Cycle - Five Phases: Requirements, Architectural Design, Detailed Design, Code and Development Test, and Formal Test
    - Partial Life Cycle - One or More of the Pre Code and Development Test Phases Not Supported with IV&V

Tabulated Statistics

- IV&V Problem Reports Identified Problem Severity and Phase in Which Defect Was Detected
- Case Study Focused on Defects Detected During Development and Test with Severity Rating Ranging from Mission Critical to Maintenance Action Required

Category Identification	Number of CSCIs	Number of Function Points	Number of Defects During Development & Test	Development & Test Defects per 1K Function Points
Full Lifecycle	8	3482	237	68.1 per 1K FP
Partial Lifecycle	4	1832	369	201.4 per 1K FP

Nearly Two-Thirds Reduction in Defect Density With Full Lifecycle IV&V

Value of IV&V

- 133.3 Fewer Defects Per 1K FP Need Correction During Code and Development Test

Value of IV&V = 133.3 * (Defect ID Costs + Defect Repair Costs Differential)

- Defect ID Costs = Cost of Identifying a Software Defect During Code and Development Test
  - Estimated at 6.8 to 8.5 Hours per Defect (Data from Watts Humphrey [1])
- Defect Repair Costs Differential = Difference in Costs Associated with Repairing a Defect During Code and Development Test as Compared with Cost to Repair During Requirements and Design
  - Estimated at 4 Hours per Defect (Data from Capers Jones [2])
- Using 160 Hours for a Person Month

Value of IV&V:

Between *9 and 10.4 Person Months per 1K FP*

Cost of IV&V

- Total Person Months Expended on IV&V = 49.75

  ➡ **14.3 Person Months per 1K FP**

- Proportion of Total Associated with Requirements, Architecture and Detailed Design Phases
  - Published Air Force Data [3] Estimates as 37% to 53%
  - IV&V Participant Estimates as 35% to 45%
  - Study Uses Range of 40% to 50%

Cost of IV&V:

Between 5.7 to 7.2 Person Months per 1K FP

Return on Investment (ROI)

IV&V ROI = Value of IV&V / Cost of IV&V

⇒ ***1.25 ≤ IV&V ROI ≤ 1.82***

- A Reduction in These Numbers (Decreased ROI) Can Be Argued Based on the Inclusion of Fixed Costs Associated with the Test Environment in the Defect Identification Costs
- An Improvement (Increased ROI) Can Be Argued Based on the Fact that Not All of the 133.3 Defects Per 1 K FP Would Likely Be Found During Code and Development Test
  - Industry Data Supports a 5% Leakage Rate (Capers Jones [2])
  - Implies 6.5 Defects Per 1K FP Would Still Be Present During Formal Testing

IV&V Can Reduce Total Ownership Costs

Other Value Additions From IV&V

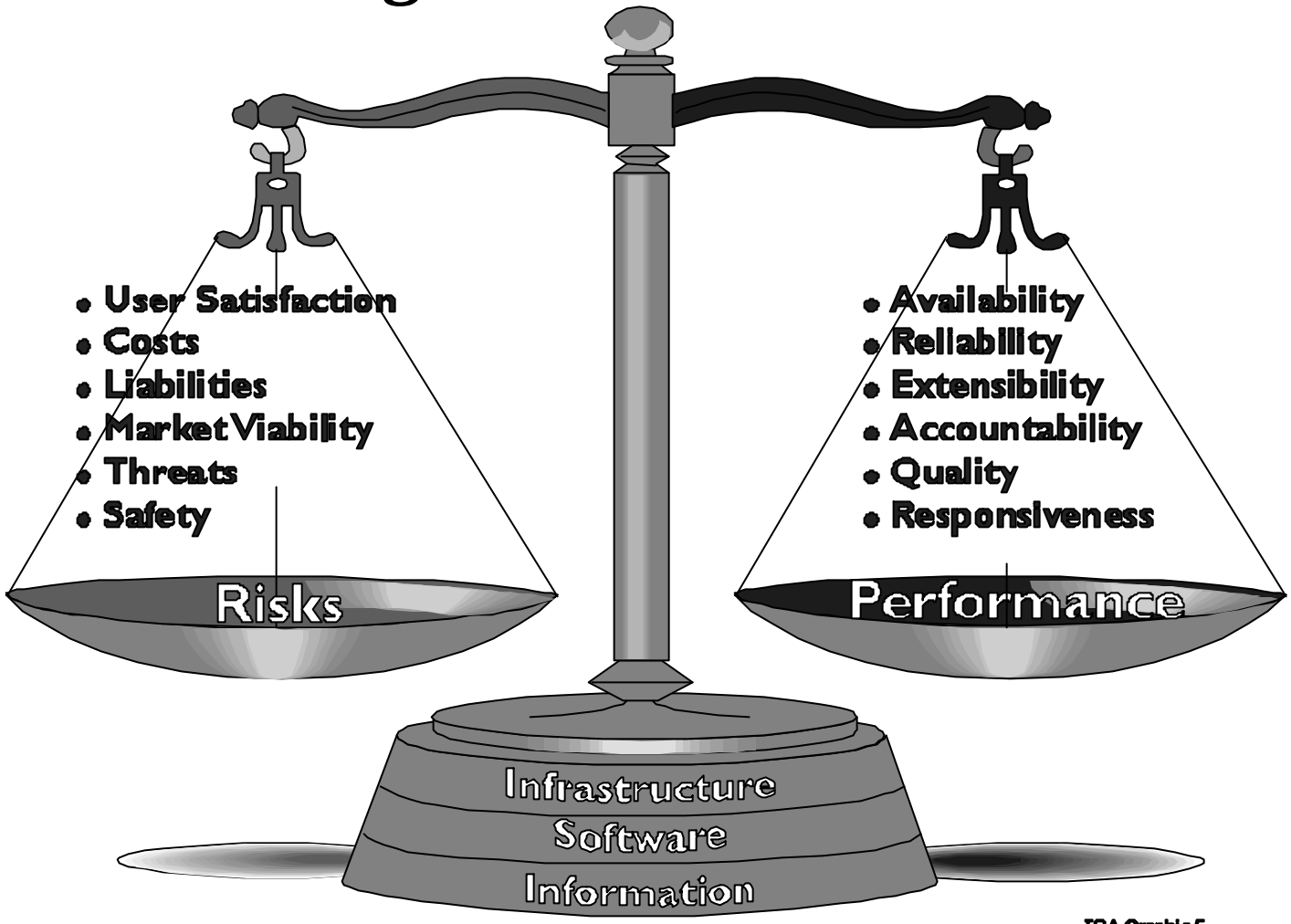
- Watchdog Effect - The presence of an IV&V contractor makes the developer more conscientious and less likely to cut corners
- Improved Maintainability - IV&V reviews improve the accuracy, readability and general usability of system documentation
- Better Understanding and Response to Risks - IV&V offers impartial evaluations and recommendations as to how to proceed
  - IV&V Can Make the Case for Difficult Alternatives
    - Schedule Slips
    - Cost Increases
    - Project Termination

Cost Impacts of These Effects Can Greatly Override IV&V ROI Numbers

Cost Effectiveness: a Second Look

- Attempts to Quantify IV&V ROI Generally
  - Tabulate and Categorize IV&V Problem Reports
  - Analyze Problem Reports to *Estimate*
    - When Developer Would Likely Find Same Error
    - Increased Repair Costs Due to The Delay
  - Sum These Repair Costs and Compare to IV&V Costs
- An Alternative for CMM Level 3 Rated Developers
  - *Estimate* Total Cost of Development Based on Historical CMM Metrics for the Organization
  - Adjust Cost *Estimates* for Changes as Project Proceeds
  - At End of Effort Compare Cost Differential Between Actual and Estimated Costs (Adjusted) to IV&V Costs

Total System Assurance
Balancing Risks and Performance



TSA Graphic 5

References

[1] Watts Humphrey, *A Discipline for Software Engineering*, Addison-Wesley Publishing Company, Reading, MA, 1995

[2] Capers Jones, *Software Quality: Analysis and Guidelines for Success*, International Thomson Computer Press, Boston, MA, 1997

[3] Air Force Systems Command, *Software Independent Verification and Validation (IV&V)*, AFSC AFLC Pamphlet 800-5, 1988